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INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1997

R. D. NEIFELD

APRIL 1998



US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

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In principle, the resistivity of bulk face-centered-cubic (fcc) materials should not depend on the orientation due to the fact that the conductivity tensor is single valued. However, we show that this conclusion is not valid for thin films. Deposition of highly oriented aluminum, silver, and copper films on amorphous substrates using the partially ionized beam (PIB) technique exhibits a resistivity that is strongly correlated with the texture, i.e., the tighter the texture, the lower the film resistivity. We model the film as an array of grains whose grain boundaries can be considered as delta function potentials for electron scattering, and the strength of the potentials can be calculated from the measured resistivity of the films. On the other hand, the fiber texture distribution of the films is obtained from X-ray pole figure measurements, and Monte-Carlo simulations are then performed using these data to determine the average dislocation density at the grain boundaries due to the grain-to-grain crystallographic mismatch. We show that the transmittance coefficient for electron scattering, and therefore, the film resistivity, is a monotonically increasing function of the average dislocation density. We, therefore, conclude that the structure of grain boundaries in a thin film provides the necessary mechanism by which the resistivity of an fcc cubic metal can depend on the texture.				
14. SUBJECT TERMS				15. NUMBER OF PAGES
Partially Ionized Beam Deposition, Al Copper Films, Resistivity, Monte-Carl	uminum Films, Silver Films, o Simulation, Electron Transport	i ,		11 16. PRICE CODE
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6. AUTHOR(S)

V.J. Olmstead and S. Tauscher

TO MULTI-LUG BREECH MECHANISMS

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13. ABSTRACI (Maximum 200 word)

A fatigue study was conducted to evaluate wire electrical discharge machining (EDM) as a manufacturing method for the production of the intricate lug geometry on multi-lug breech mechanisms. The wire EDM process produces a thin surface layer of recast material that was found to have an adverse effect on specimen fatigue life. Removal of the recast layer is recommended on highly stressed critical components.

Unidirectional bending fatigue tests were performed utilizing notched rectangular test specimens made from ASTM A723 steel material. The fatigue tests compared wire EDM prepared surfaces to those produced by the conventional drilling and honing process. The effects of multiple EDM passes and post-processing techniques such as bead blast cleaning, shot peening, and mechanical overloading were investigated.

The recast layer was found to have a significant detrimental effect on specimen fatigue lives. Fatigue life reductions of 20 to 40 percent were observed. The deleterious effect on fatigue increases as the applied stress decreases. The post-processing techniques improved lives but they were generally inferior to those that were conventionally machined and treated with the same process. In limited testing, the combination of glass bead cleaning and mechanical overloading provided "significant" improvement in life compared to either process applied individually.

14. SUBJECT TERMS EDM Recast Layer, Fatigue, Glas	15. NUMBER OF PAGES 29		
Multi-Lug Breech Mechanisms, O	verload, Shot Peen, Wire EDM		.16. PRICE CODE
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6. AUTHOR(S)				
Anthony P. Parker (Royal Military Co Stephen N. Endersby (U. of Northumb John H. Underwood, Sabrina L. Lee, a	oria, UK), Timothy J. Bond (U. o	f Northumbria, UK),		
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Elastic, elastic-plastic, and experimental stress analyses and fatigue lifetime predictions are presented for thick cylinders containing multiple, axial holes within the wall. The holes are generally semi-elliptical (including semi-circular) and the cylinders are autofrettaged after introduction of the holes and are subsequently subjected to cyclic pressurization of the bore.				
Two potentially critical failure locations are identified; a fracture-mechanics based design methodology is proposed; elastic and elastic-plastic finite element (FE) analyses are undertaken. The elastic FE analysis predicts hoop stresses at the bore resulting from internal pressurization which are some 7% higher than those for the equivalent plain tube. For a given hole size and location and for nominal overstrains of 40% or greater, the residual compressive stress at the bore is reduced by approximately 15% below the value for a plain tube of the same radius ratio.				
Two experimental investigations are reported, one based upon X-ray diffraction, to measure residual stresses, and the other based upon radial tube slitting, to measure opening angle. They confirm most features of the residual stress profiles predicted from FE analysis, with the exception of high compressive residual stresses and stress gradients immediately adjacent to the hole boundaries. Appropriate use of the residual stress information permits prediction of tube lifetimes for cracks emanating from the bore and from the hole. For the geometry and loading under consideration, the more critical location is predicted to be the hole boundary, the lifetime for failures originating from this point being some 60% of the lifetime for cracks originating at the bore.				
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6. AUTHOR(S)					
Samuel Sopok, George Pflegi, Peter O'l Stuart Dunn*, and Douglas Coats* * Software and Engineering Associates.		•			
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The MACE gun barrel thermochemical cracking coupled with pure mechanical information that is otherwise impraction materials are evaluated for erosion us evaluated scientific theory that has been the standard interior ballistics gun coo (CCET), the standard mass addition to conduction erosion rocket code modificablation, conduction, and erosion profit to barrel condemnation. These original profite code (FDHEAT) and actual meaning the standard mass addition to barrel condemnation.	erosion for the original M2 cal. The A723, 0.002-inch ing the M242 Cycle A firiten validated in the rocket cole (XNOVAKTC), the standoundary layer rocket code fied for guns (MACE). This les) as a function of time, trail M242/M919 gun system in	42/M919 gun system plated chromium/Aing scenario. This community over the laterd nonideal gas-we modified for guns analysis provides avel (customer-selectoredictions agree we	n. This predictive to 723, and 0.002-inch complex computer ar ast forty years. Our all thermochemical r (MABL), and the st wall material erosion ted 6-inch, 12-inch, 3	sputtered tantalum/A723 wall alysis is based on rigorously gun erosion analysis includes ocket code modified for guns andard wall material ablation predictions and comparisons 0-inch), and number of rounds	
14. SUBJECT TERMS	14. SUBJECT TERMS				
Modeling Code, Thermochemical Eros Ablation, Mechanical Erosion, M242/	Modeling Code, Thermochemical Erosion, Erosion Predictions, Gun Barrels, Thermochemical Ablation, Mechanical Erosion, M242/M919 Gun System, Chromium, Tantalum 26 16. PRICE CODE				
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This paper presents an applied met cannons. The method uses a fini approximation. This model is then the design is optimized by assigning minimizing the design parameter space cut in half by an appropriately to modeling uncertainty is significantly	te element model of the cannon, transformed to the Laplace "s" doing a scalar cost function to the free pace. The results indicate that the upper 20 Kg absorber located at the	which was formulated using the main (transfer function form) using equency response of the modified peak amplitude of the frequency to muzzle. Also, sensitivity of the	the Euler-Bernoulli transverse beam to the MATLAB® software package. barrel, which provides a metric for response of a 1,500 Kg barrel may be design to parametric variation and	
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Edward Troiano, John H. Underwood, As G. Peter O'Hara, and Daniel Crayon	nthony Scalise,		·	·
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A pressure vessel, which was designed and Thousands of oscillatory pressure reversa the critical threshold values necessary to	ls were measured at each loading. initiate fatigue cracking.	However, the predominar	ice of the stre	s ampitudes were wen below
Analysis demonstrated that the disparity bet Further investigation into the problem ret the pressure vessel, along with high tempo vessel.	vealed that an extremely aggressive	e environment, the by-proc	lucis of the m	CELIST COTHORSHOIL HOLL ATTITUTE
14. SUBJECT TERMS Low-Cycle Fatigue, Pressure Oscillation Hoop Stress, Radial Stress, Fatigue Crae	ns, Pressure Vessels, Cumulative I cks, Palmgren-Miner Rule, Environ	Damage Model, Residual S Inmentally-Assisted Cracki	tresses,	15. NUMBER OF PAGES 16 16. PRICE CODE
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6. AUTHOR(S)			
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compact specimen. The bolt-loaded species tested were A723, Maraging 200, Pt-chemical composition, refinement, heat all high strength steels tested exhibite crack growth rates up to three orders of base alloys exhibit different crack growth and heat treatment had some effect cracking. When the weld strength of or	cimen was subjected to both acid and e	electrochemical cell environments A 286, ranging in yield strength induced crack growth rates and the hold levels. In comparison, the nather the steels tested. It is widely known tent crystal cell structure. In the laugh strength was the predominal as increased moderately, from 11	on that high-strength steels and nickel high-strength steels tested, refinement nt factor influencing susceptibility to 30 MPa to 1275 MPa, the incubation
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Hydrogen Embrittlement, Environmental Fracture, Environmental Cracking, Crack Growth Rates, High-Strength Steels, Nickel-Iron Base Alloys			16. PRICE CODE
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Combustion gases containing hydrogon Although the hydrogen is evolved at ambient temperature.	en can cause severe environment the elevated temperatures of com	al degradation and cracking bustion, the deleterious ef	ng in the high st fects of hydrog	trength steels used in gun tubes. en on steel are most severe near	
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Sequences of thermographic image	es of burning residue produced by l	M198 155 (unicharge) tes	t rounds fired at Yuma Proving Ground	
(YPG) were collected for analysis to	o elucidate the evolution of condition	ns in the breech after firin	g and to provide guidance in determining	
safe loading protocols for future a	utoloaders. In order to better unde	rstand the thermal enviro	nment in the breech, we are developing	
advanced analytical tools that can t	be used to quantitatively characterize the temperature profiles the YPG the	e sequences of mermograp	ohic images. However, for this study the see analyses was unavailable. No analytic	
colution could be determined to be	erform the highly nonlinear reverse	transformation from KGE	s space to intensities; dieterore, a neural	
network was employed. Furthermo	re, the experimental data provided by	YPG were only measural	ole over a restricted range of temperatures	
extending from approximately 80°C up to 110°C. Since the highest temperatures measured in the thermographic data did not correspond				
to a hazardous condition, more complex measures than simple statistical averages of the temperature had to be used. A new numerical				
technique represented by sparse data sets was introduced for measuring the scaling properties of single-valued surfaces in 3-space.				
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14. SUBJECT TERMS				
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6. AUTHOR(S) Samuel Sopok, Peter O'Hara, Patricl Christopher Rickard, and Richard Lo	v Vottis, George Pflegl, comis (PM-TMAS, Dover, NJ)				
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The Benet Laboratories/Software and Engineering Associates, Inc. (SEA) gun barrel erosion modeling and design code predicts wall degradation due to transformations, chemical reactions, and cracking coupled with pure mechanical erosion for the 120-mm M256/M829A2 gun system for ambient temperature-conditioned rounds. The A723 steel and 0.005-inch high contraction (HC) chromium plated/A723 steel wall materials are evaluated for erosion. This complex computer analysis is based on rigorously evaluated scientific theory that has been validated in the rocket community over the last forty years. Our gun erosion analysis includes the standard interior ballistics gun code (XNOVAKTC), the standard nonideal gas-wall thermochemical rocket code modified for guns (CCET), the standard mass addition boundary layer rocket code modified for guns (MABL), and the standard wall material ablation conduction erosion rocket code modified for guns (MACE). In addition, bore subsurface metallographic analysis and projectile-bore finite element analysis (ABAQUS) are considered. Our overall analysis provides wall material erosion predictions and comparisons of ablation, conduction, and erosion profiles as a function of time, travel (customer-selected 27, 61, 86, 130, and 201 inches from the rear face of the tube), and number of rounds to barrel condemnation. The 120-mm M256/M829A2 gun system prediction, with significant numbers of M829A2 rounds, agrees well with the wear and erosion pattern of retired M256 gun barrels.					
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This paper presents an applied method cannons. The method uses a finite	od for the optimal design of passivelement model of the cannon. The	ne design is optimized the	reduce terrain-induced vibrations of tank by assigning a scalar cost function to the frequency response of a 1,500 Kg barrel ults using modal impact testing are shown.	
14. SUBJECT TERMS Vibration Absorbers, Passive, Desig Gun Barrels, Finite Element Method	n, Cannons.		15. NUMBER OF PAGES 15 16. PRICE CODE	
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During the design and development of weapon systems, it is imperative to evaluate prototype components for the purpose of validating theoretical calculations and predictions made earlier in the design process. This report describes strain characterization testing conducted on 155-mm XM297 Test Cannon #1 for the purpose of validating calculated strains from the swage autofrettage process, evaluating fatigue life of various midwall and outer wall geometric configurations, validating calculated strains from simulated service life conditions, determining the maximum pressure containment capability of the cannon, and finally, determining the failure mode of the cannon.

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to be a viable means for extending	the overall life of components. A also suggests that, although crac Because most point defects will b	lithough technically correct,	ow cycle fatigue regime does not appear the model did not accurately predict the ll specimens, some damage could not be atment, it is believed that non-detectable
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thick cylinders. The model employed	Bauschinger effect upon residual: d allows for the variation with rad	lius of Bauschinger Effect Fa	the lifetimes for pressurized, autofrettaged actor (BEF) throughout the autofrettaged at the bore to zero at the elastic-plastic
maximum value at the percentage of	verstrain level below which reverces are shown to support this the	rsed yielding does not occur	the inner radius of the tube reaches a r. Existing experimental residual stress may serve to maximize crack initiation
governed by a crack growth law such in excess of that for the onset of rev value at overstrain levels in which y overstrain leads to a small increase	n as Paris's Law. For a tube of radersed yielding, the fatigue lifetime rielding reaches 1.4 times bore rade in residual stress at the outside diginating at the OD. Existing exp	lius ratio 2.0 and at a value of e exhibits a maximum value dius and are almost constant liameter (OD), thus increasing	to consider fatigue crack growth rates f approximately 40% overstrain, slightly. Fatigue lifetimes achieve a maximum thereafter. Furthermore, such extendeding R ratio at that location and reducing ments are shown to require the inclusion
14. SUBJECT TERMS	T. C. J. Postova Lifesima	C. dindon	15. NUMBER OF PAGES 25
Bauschinger Effect, Crack Growth, Fracture (Materials), Fracture Mechanic	Fatigue Cracks, Fatigue Lifeume anics, Residual Stress, Stress Inte	s, Cylinders, ensity Factor	16. PRICE CODE
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occurred in similar prototypes of ar residual stresses, environmental con Laboratory hydrogen cracking tests of to model the hydrogen cracking. The strength ASTM A723 forged steel of grown after thirty firing cycles near yield strength PH 13-8 Mo stainless high strength steels, was the sustained components. Recommended preversidations of the strength steels.	n advanced cannon over a two-yes aditions, and the resulting cracking of the cannon materials, finite elem the first cracking incident involved of cannon tube, following five firing of the seal between two adjoining consteel. The cause of cracking, given the tensile stresses arising from assemble the seal between two adjoining consteels.	ar period. The materials g behaviors and SEM fra ent stress analysis, and streacks up to 21-mm long cycles. The second incidanton components, one nut the presence of hydrogenembly preloads required to the strength level of the	tents is described. Two cases of cracking components configurations, applied and cture surface characteristics are outlined. ess intensity factor calculations were used mear a pressure seal in an 1160 MPa yield ent involved 50-mm long cracks that had hade from A723 and one from 1280 MPa-laden propellant products and susceptible or maintain pressure seals between cannon e existing martensite steels, changing to entrations in areas subjected to propellant
14. SUBJECT TERMS Hydrogen Cracking, Pressure Vesse	ols High Strength Steel, Environm	ental	15. NUMBER OF PAGES 20
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This report documents the performance Laboratories—during bump-course te tuned shroud reduces the receptance of this will enhance the accuracy of the launch dynamics. The test results detail a factor of four reduction in the power approach using existing hardware can	sting on a modified M1A1 tank as of the gun barrel to vibrational endeapon system by reducing variationstrated that one of the three constrained that one of the first beginning to the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning of the first beginning on the first beginning on the first beginning on the first beginning on the first beginning of the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the first beginning on the	at Aberdeen Proving Ground or nergy while the tank traverses a lation in the initial conditions of configurations tested reduced vo- ending mode. Thus, the testing	ough terrain. It is anticipated that of gun barrel flexure at the start of rtical flexure by 24% overall, with demonstrated that a simple passive
14. SUBJECT TERMS			15. NUMBER OF PAGES
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The manufacture of some baseplates, no weldment that has more than 64 parts jo have simple dynamic acceptance criteri	ointed by no less than 100 feet of	weld-joints. It follows the	type of baseplate consists of a monocoquent that it would be highly advantageous to ed "ringing check-out tests."
experimental modal analysis. The inforthese type of structures. The informatic acceptance criteria for assessing mortar investigation includes the results of more	mation may be used to validate as tion also may be utilized as a ba baseplate quality, notably the presentation of the presentation.	dvanced FEA theoretical in aseline for developing the sence of undesirable defects to from the structure. The	0-mm mortar baseplate through the use of models relative to the dynamic behavior of a aforementioned manufacturing "ringing cts such as gaps, poor weldments, etc. Ou results are presented in computer animation are compared to theoretical predictions of
14. SUBJECT TERMS			15. NUMBER OF PAGES
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If a projectile is loaded into a hot cannon tube, the heat from the cannon starts to raise the temperature of the seated round. If not fired quickly (as in a misfire, checkfire, or hangfire situation), the projectile temperatures may increase to a critical point where the high explosive (HE) filler will start to melt, expand, and chemically separate in a process called "exudation." When this occurs, the melted filler becomes more sensitive to detonation, and the rapidly increasing volume of the HE can force the liquid filler out of the fuze threads onto the bore of the hot tube. In the latter event, the probability of an inbore detonation increases dramatically with the possibility of injury to the crew and damage to the cannon platform. This report documents the results of an experiment in which two common 155-mm HE projectiles (the M107 and the rocket-assisted M549A1) were preconditioned to an initial temperature, then rammed into a tube (which itself was preconditioned to a different initial temperature). Time-temperature data for both the projectiles and the tube were gathered, and the reduced data are presented herein.

14. SUBJECT TERMS Cannon, Cannon Tubes, Projectile,	155-mm M549A1 Projectile, 155-m	um M107	15. NUMBER OF PAGES 39
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